ALCOHOL FROM AGRICULTURAL SOURCES AS A POTENTIAL MOTOR FUEL

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A great deal of research is being done in the United States to develop new and cheaper methods of producing alcohol from agricultural raw materials and to utilize it as motor fuel. It has long been known that various farm products and byproducts can be used for alcohol production. These include grains and other starchy crops, such as potatoes; saccharine materials, such as the molasses byproducts of the cane-sugar and citrus industries; cellulosic materials obtained as crop residues, such as corncobs, oat and cottonseed hulls, sugarcane bagasse, and flax shives; and the sugar-containing wastes produced in large quantities in the United States by the fruit and vegetable processing industries. The Bureau of Agricultural and Industrial Chemistry of the U. S. Department of Agriculture is engaged in research on the production of alcohol and other products from all these materials.

As you may know, much of the industrial alcohol used in the United States today is manufactured synthetically at relatively low cost from natural gas and from the gasses obtained in the cracking of crude petroleum to produce gasoline and other fuels. The present prices of corn, wheat, and other grains, and the limited demand for industrial alcohol, make it difficult for alcohol from grain to compete with that produced, almost as a byproduct, in petroleum refining. Of course, shortages of petroleum or natural gas, lower grain prices, or increased demands for alcohol could change this picture.

Under present procedures, the cost of producing ordinary 95-percent alcohol from corn selling at $1 per bushel is in the range of 40 to 50 cents per gallon. If the cost of corn were reduced to 75 cents a bushel, the alcohol could be made for 35 to 40 cents a gallon. The example of corn at $1 per bushel is cited here, in spite of the fact that present corn prices are much higher, because if large quantities of this grain should accumulate in the United States the price might well fall to $1 per bushel or even lower. At the same time, it is well to remember that alcohol from sugarcane molasses or that produced by synthesis from petroleum cracking gasses now sells for 25 cents a gallon or less.

Development of methods for lowering the cost of producing alcohol from grain is a major objective of the work at the Department's Northern Regional Research Laboratory. In this research, efforts are being made to decrease alcohol-production costs in three ways; (1) by lowering the cost of processing, (2) by increasing the yield of alcohol, and (3) by raising the value of fermentation byproducts -- for example, by refermentation to increase their nutritive value in stock feeds, and by using them for the production of vitamins or other biologically valuable compounds.

Considerable progress has been made in lowering the cost of processing. During the past few years, a submerged-culture method of producing a mold which can completely replace malt in fermentations has been developed. Use of this mold reduces the cost of grain-alcohol production several cents per gallon, and the process is already being applied commercially, although needed additional research on it is still in progress.

In the production of alcohol by the yeast fermentation of grain or other starchy material, it is necessary first, of course, to convert the starch into sugar. This is easily accomplished by the use of barley malt, which contains starch-converting enzymes, or amylases. However, malt is rather expensive. As a result of a survey of more than 350 fungi, workers at the Peoria laboratory discovered several organisms capable of producing starch-hydrolyzing enzymes in submerged culture. They found that culture liquor from one strain of the mold Aspergillus niger (NRRL 337) could replace malt completely when it was added to corn mashes in the proportion of 10 to 20 percent of the final mash volume. Pilot-plant experiments demonstrated that operation of the process for using this "fungal amylase" in place of malt was feasible for large-scale commercial operations. We have shown that a distillery can save from 6½ to 9½ cents per bushel of grain mashed by utilizing the mold-amylase liquor instead of malt in fermentations. This amounts to a saving of 2½ to 3½ cents per gallon of 190-proof alcohol produced.

Experiments on the fermentation of corn sugar, supplemented by animal stick liquor and corn steep liquor, have resulted in a process for production of riboflavin, a vitamin essential for human and animal nutrition. This method has been successfully applied on an industrial scale.

Studies are also under way to develop economic methods for refermentation of stillage to yield feeds of higher nutritional value by the biosynthesis of B-complex vitamins.

The fact that gasoline sells in the United States for about 25 or 30 cents a gallon including federal and state taxes and that grain alcohol, even from corn at only $1 per bushel, would probably have to sell at 40 to 50 cents per gallon indicates that alcohol must possess some outstanding fuel characteristic which would permit it to sell at a premium price, unless its cost of production can be drastically reduced or offset.

Researchers at the Northern Laboratory have therefore studied the fuel characteristics of alcohol in an effort to determine whether it has any outstanding properties as a motor fuel, and to evaluate the economic position of alcohol when used as fuel in various ways. The most significant development resulting from their studies -- a development I believe will be of interest to many countries -- is the use of alcohol as an anti-knock agent by direct, automatic injection into the intake manifolds of automotive engines.

Until recently, alcohol has been employed as motor fuel chiefly in blends with gasoline. A number of other countries have had more practical experience with this method than we have in the United States. As a motor fuel, pure alcohol surpasses isooctane on the Research Method octane scale, having a rating of 100 plus 1.4 milliliters of tetraothyl lead per gallon. In other words, alcohol is equivalent to isoooctane containing 1.4 milliliters of totracthyl lead. I might mention here that the so-called Motor Method octane number of ethanol is 92; however, it is the Research number which gives closer correlation between the rating of the engine on the road and that in the laboratory, particularly for higher-compression engines.

On the basis of potential power output, fuels of higher octane numbers are much more valuable than those having numbers in the lower octane range. It is also true, however, that an engine yields only so much power as it can produce when using a fuel with an octane rating just sufficiently high to give knock-free operation. Use of fuel having an octane number higher than is required for this purpose does not provide additional power and hence is not necessary.

Addition of alcohol to gasoline simply makes a premium-grade or high-octane motor fuel out of lower-octane gasoline. For example, a certain type of regular 74-octane gasoline, plus 25 percent anhydrous ethanol, will have a Motor Method rating of 86 and a Research Method rating of 97, much higher than the octane rating of any presently marketed premium-grade gasoline. Anhydrous alcohol must ordinarily be used in blends, because of the low water tolerance of gasoline, and it may cost 5 cents or so per gallon more than 95-percent alcohol.

A blend of alcohol and regular gasoline in the ration of 1 to 9 -- that is, a 10-percent anhydrous-alcohol blend -- gives excellent performance in the average engine. It is equal to a good premium-grade gasoline. No change in engine design or adjustment is required, and with reasonable precautions no separation of the blended fuel because of water absorption by the alcohol will occur. Sweden has employed a 25-percent-alcohol blend very successfully diring the past 20 years, and many other countries have also made practical use of gasoline-alcohol blends.

The benefit obtained in ordinary blending of alcohol with gasoline in present-day engines is not great enough, however, for alcohol to command a premium price over gasoline for this purpose, at least in the United States. To be competitive when used in a blend, alcohol would have to sell in America at essentially the same price as gasoline.

But as I suggested, a much more promising method of using alcohol as a fuel is by separate, automatic injection into the engine manifold. This was an important development for military aircraft operations during World War II. Alcohol was used to give planes an extra burst of speed under certain combat conditions and also enabled aircraft engines to produce the extra power needed for take-off without injury to the engines.

Since the war, alcohol-water injection has been adapted for use in automobiles, trucks, and other vehicles. In this case, however, it is not employed to permit the development of momentary increases in engine power, but rather to improve the octane ratings of available fuels. With alcohol injection, an engine supplied with a low-octane gasoline -- for instance, with an octane number of 60 -- can perform as satisfactorily under load as if it were being supplied regular or high-octane fuel. Ordinary 95-percent alcohol can be used for this purpose, and the additional cost of anhydrous alcohol necessary in blends can be avoided.

Whether used in a blend or mixed with water and fed directly into the engine by a supplementary carburetor, alcohol markedly improves the anti-knock rating of gasoline. But in blends, of course, it is supplied continuously to the engine, even when the vehicle is traveling at a regular speed on level ground and does not actually require high-octane fuel. The advantage of the direct-injection method is that the alcohol is used only when needed -- that is, when the vehicle is under heavy load, as in starting, accelerating, or climbing hills. This occurs only during about 5 percent of normal driving time. Since manifold vacuum is a direct measure of engine load, this force is used to control injection. It allows the alcohol-water mixture to enter the carburetor air stream when the engine is under such load that its octane requirement is above that of the basic fuel.

Using alcohol in this way, as an anti-knock agent is the most efficient method of employing it as motor fuel. This procedure also permits efficient use of relatively low-octane and less expensive gasoline as the main fuel during 95% of normal driving time. Because more low-grade gasoline than high-grade can be produced from a given quantity of crude petroleum, alcohol injection offers an opportunity for significantly extending a nation's petroleum resources or reducing petroleum imports.

Alcohol-water mixtures injected into engines effectively increase the octane rating of gasoline by about 20 octane units. This is due both to the high octane value of the alcohol itself and to the high heat of vaporization of the alcohol and water mixture. Road tests, conducted over hilly and flat terrain and involving some city driving, show that the amount of fuel used for efficient operation of an automobile is in the ratio of only 1 gallon of alcohol-water mixture for every 50 to 65 gallons of gasoline consumed. This ratio may be even lower when more efficient injectors are developed.

The equipment needed for alcohol-water injection is relatively simple. It is essentially an accessory carburetor, located near the ordinary carburetor immediately above the engine and connected with a small alcohol tank, which may be placed -- at least in American vehicles -- under the hood. The required capacity of this tank is about 1 gallon. In ordinary automobile operations, it is necessary to fill the alcohol tank only about every 750 miles of driving, depending somewhat on the make of car and the type of operation. Considerably more alcohol, of course, it normally required for truck operation.

Estimated cost of a commercial alcohol-injection device, including the gallon tank and other accessories, is at present about $35. One such device is now on the market in the United States. Only a few hours' work is required to install this equipment.

One factor which favors the eventual use of alcohol-water injection is the current trend in the automotive industry toward high-compression engines. The average compression ratio for all American cars in 1949 was 6.67:1, with a maximum of about 7.25;1. The trend is toward even higher ratios -- 10:1 or 12:1, for instance. These higher-compression engines have greater fuel economy and give greater mileage per gallon of gasoline. However, they will require super-octane gasoline for knock-free operation. There is some doubt as to the ability of petroleum refiners to furnish, economically, sufficient quantities of super-octane gasoline for these engines in the years to come, particularly if they are generally adopted for use in automobiles. Alcohol-water injection, used in conjunction with present-day gasolines, is one of several ways of meeting the possible demands for fuels of higher-octane values than those presently available.

Although alcohol-water injection is a very promising development, much additional research needs to be done on it. Extensive road tests are now being conducted by the United States Department of Agriculture to discover whether there are any special lubrication problems involved in operating an automobile with alcohol injection and to learn also whether the wear on the engine is greater than normal. Through these continuing practical trials we hope to determine the best means of utilizing alcohol injection under all types of operating conditions and, if possible, to determine the premium that alcohol could command over gasoline as a result of the increased efficiency it would give in motor operation.

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